vermicelli soup. The eggs and spermatozoa are discharged and nothing is left but empty skins scarcely visible.

Professor Michelson described his important invention of a spectroscope without prisms or gratings made by building up steps of equal thickness of optical glass. With twenty elements 5 mm. thick the resolving power would be 100,000 which is about that of the best gratings. The method is especially important for the examination of single lines and the study of the effects of broadening, shifting or doubling of lines. Dr. Gill read a biographical memoir of Edward D. Cope, based on his address as President of the American Association, which has been published in this JOURNAL. President Mendenhall gave the results of further researches on the lengths of words used by different authors. He is able to show graphically a characteristic curve for a writer, and thus has found a method by which disputed authorship may be tested.

Dr. J. S. Billings resigned the office of Treasurer on account of his removal from Washington, and Mr. Charles D. Walcott was elected in his place. Messrs. Billings, Bowditch, Brush, Hague, Marsh and Newcomb were re-elected additional members of the Council for another year.

No new members of the Academy were elected this year. This appears to be unfortunate, as only thirteen elections have been made during the past eight years, whereas the Academy has lost twenty-eight members by death. The Academy can, by its constitution, only elect five members annually, and as the deaths are likely to amount to nearly this number it is difficult to see how the membership can be maintained if, in certain years, no members are elected, as was the case in 1891, 1893, 1894 and this year.

A large addition was, however, made to the foreign associates of the Academy, whose number is limited to fifty, as follows:

Professor Henri Poincaré, Paris; Dr. David Gill, Cape Town; Lord Rayleigh, London; Professor Adolf von Baeyer, Munich; Lord Lister, London; Professor Edward Suess, Vienna; Professor H. de Lacaze-Duthiers, Paris; Professor Edward Strasburger, Bonn; Professor Felix Klein, Göttingen; Professor Henri Moissan, Paris; Professor Karl Alfred von Zittel, Munich.

The autumn meeting of the Academy will be held at New Haven, beginning on November 15th.

## *SOME AIDS TO THE STUDY OF STEREOSCOPIC VISION.*

THE familiar form which the stereoscope has assumed since Brewster, together with the marked development of photography, has brought about a general appreciation of the striking and frequently beautiful effect which this instrument produces. This form of the apparatus, however convenient, is not best suited to the exposition of the underlying principles of the stereoscopic illusion. These principles involve the general problem of the perception of depth or solidity, and this, in turn, is a rather complicated matter, which involves many details. An important service which the stereoscope performs for the psychologist is the aid which it renders him in the analysis of these factors. Some of the more or less recent variations in the form and construction of stereoscopic instruments furnish added facilities for the demonstration of the factors which enter into the perception of depth. To furnish a brief account of these various aids to the study of stereoscopic vision is the purpose of this article.

One of the most frequently discussed points is the dependence of the appearance of solidity upon the dissimilarity of the two stereoscopic pictures, which, in turn, imitate the differences of the retinal images in the two eyes. The truth of this view can be established be-

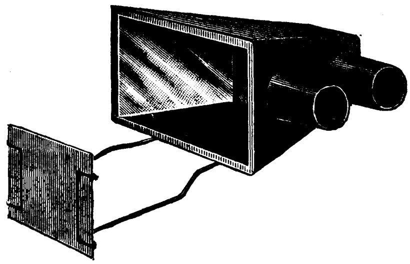
yond any reasonable doubt, and is proved by the fact that all instruments which really produce this appearance of depth, however much they may differ in other respects, must furnish some systematic differences in the two pictures to be viewed. It is evident, however, that this aid to the perception of depth will differ considerably according as the object represented is near or far away. For near objects the differences in the retinal images will be quite marked, while for distant ones the images will be more nearly alike. To magnify the perception of depth in distant views Helmholtz devised the telestereoscope, which acts by practically spreading the distances between the eyes, and which, in combination with lenses, finds a useful application in stereoscopic field glasses. The processes of convergence and accommodation accompany these differences in the retinal images; and these, too, are more active in the perception of near objects than of distant ones. In order to determine which of the two factors, convergence or difference in the retinal images, is the more essential it is necessary to produce one more or less independently of the other. This can be done, first, by viewing in the ordinary stereoscope two views which are precisely alike and which are superimposed by means of convergence; and, again, two views which differ as the two retinal images differ and which are combined with a minimum of convergence by means of devices described further on. The result is unmistakable and shows that convergence is only an added element and that the difference in the retinal images is the all-important factor.

But apart from these factors, which may be expressed in physiological terms—that is, in terms of what goes on on the retina and within the eye and eye-muscles—there are psychological factors in the perception of depth which materially influence the result. While the former are either simple sensations or the inferences from them, the latter involve more complicated forms of interpretation on the basis of perceptions which are the result of a varied experience. First among these is the distribution of light and shade. This factor is so important in most of our experience in the interpretation of depth that it alone frequently determines the visual result and overrules the influence of all other factors. For example, it is not difficult to illuminate an intaglio in such a way that it can be mistaken for a cameo. In the illusion of depth which the artist produces this factor is obviously of supreme importance. A second psychological factor, likewise invaluable to the artist, arises from our constant tendency to interpret outlines and contours as the representations of three-dimensional objects. As a result of our general experience, we are quite prepared to interpret all lines in a painting or an etching or a photograph as representing certain views of objects. We know, of course, that the pictures are flat, but we see them as solid. Especially when this tendency is combined with the interpretation of lights and shadows do we have an appearance of depth which, when skillfully portrayed, seems hardly less real than the reality. A third factor equally operative in pictures and in reality is that summed up in the term perspective, which involves in the main the diminution in the apparent size of the object as its distance from the eye increases. Figures in the foreground and in the background are interpreted not according to their real size—that is, not the number of millimetres that they occupy on the retina, or of inches on the canvas—but according to these as modified by the estimated distance between the object and the point of view of the beholder. The familiarity of objects is, of course, a great aid in the proper estimation of such distances. If two men are represented upon a picture, and the one representation

is one inch in height and the other two inches, we infer (under proper conditions of perspective) not that the one man is twice as tall as the other, but that the two are of approximately similar size, and that the one is considerably more distant. As a further factor one may mention the interrupted view of a more distant object by reason of a nearer object standing in front of it. Most objects are opaque, and on this account we infer the continuity of outlines which are more or less hidden by the objects in the foreground. If, for example, we see in reality or on a picture a bush in front of a fence we do not infer that the fence is broken where the bush prevents us from seeing it, but that it is continuous and farther away than the bush.

When all these factors coöperate they produce a very complete illusion of depth, and frequently one which does not seem to require the operation of the more physiological factors of convergence and the difference in the retinal images. In the case of photographs viewed through the stereoscope we have the combination of all the above factors, and it requires a rather detailed analysis to make clear the influence of each. It is possible, however, to prove conclusively that the difference in the retinal images is the prime factor and that all the others form accessory methods for the inference of depth, but are not at all necessary for this effect. For this purpose we must have stereoscopic views which show no light and shade, no perspective, no interposition of objects. Geometrical figures theoretically constructed have been generally used for this purpose. A very superior series of diagrams has recently been published and forms an important aid to the study of stereoscopic vision. They are the result of the application of the stereoscope to the demonstration of mathematical problems, a result which has been most ingeniously reached by Professor C. S. Slichter,* of the University of Wisconsin. These diagrams represent the motion of a point in space under the influence of three forces acting respectively in the three dimensions of space. A small electric lamp suspended in a dark room is given a pendular motion, and at the same time a stereoscopic camera is itself swung in a direction at right angles to the motion of the lamp. These movements are brought into unison by means of electro-magnets, and the result is that the point of light leaves its trace on the pair of photographic plates precisely as though a pair of eyes were following the movement of the point in and out through the three dimensions of space, but that in addition the track of this point of light is retained from beginning to end. These views thus represent beautiful and intricate mathematical curves and in the stereoscope appear distinctly three-dimensional as wire forms or models. I know of nothing which equals these views in clearness and precision, and I cordially recommend them as test diagrams in stereoscopic experiments. It may be said that any instrument which succeeds in producing from a pair of such views a full and complete appearance of depth is a true stereoscope, and one which fails to do this is not a true and perfect stereoscope.

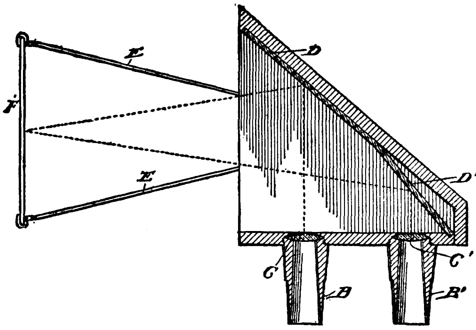
An interesting and novel type of apparatus has recently been introduced under the term of Perspectoscope. It consists in



THE PERSPECTOSCOPE.

* Transactions of the Wisconsin Academy, 1898, Vol. XI., p. 449.

the main of two eye-pieces fitted with suitable lenses and of a pair of mirrors, the two mirrors being set at such an angle that the image from a single picture which is placed at right angles to the eye pieces will be reflected into each of the eyes. The accompanying illustrations will readily make clear the principle. The



PRINCIPLE OF THE PERSPECTOSCOPE.
B. B.'—Viewing tubes. C. C.'—Lenses. D. D.'—Reflectors. E. E.—Picture Holder. F.—Picture.

inventor of this instrument claims that it disproves the accepted theory of the stereoscope, because with it one can see a single picture, such as any ordinary photograph or drawing, in apparent perspective. He further claims that in this way a true perspective is obtained, while the ordinary stereoscope is alleged to exaggerate the perspective.* These claims can be readily disproved; in the first place, the perspectoscope utterly fails to exhibit the test diagrams above described as solid; secondly, the ordinary stereoscope does not as a rule exaggerate the perspective, although such an exaggeration may be readily obtained if desired. In Professor Slichter's diagrams the motion from left to right was in reality equal in extent to the motion forward and backward. I asked a number of persons as they viewed these diagrams to estimate the breadth in terms of the depth, and the general tendency was to regard the diagram as somewhat broader than deep. Although the claims made for the perspectoscope cannot be allowed, it is true that when a photograph is viewed by the average observer in the perspectoscope there is a striking appearance of depth, quite enough to make this apparatus a popular instrument for viewing pictures. How is this effect of apparent depth produced? The answer is in the main that the accessory factors in the perception of depth are here introduced at their maximum efficiency; and added to this there is the action of the lenses in magnifying the objects, and the convenience and precision with which the views as reflected from the two mirrors may be superimposed. It is a well-known fact that a large magnifying glass is itself an important aid in the perception of the third dimension in a photograph, and this aid is utilized in the perspectoscope in a more convenient form. For the same reason the glasses in the ordinary stereoscope are not prisms but prismatic lenses.

To one who is familiar with the appearance in the stereoscope of a pair of stereoscopic views (or stereographs, as Le Conte Stevens suggests) there is something decidedly lacking in the perspectoscope effect; and yet, unless the two are viewed immediately in succession, the average observer might well be misled to regard the perspectoscope as really producing the appearance of depth. This is altogether likely to be the case if the observer happens to use stereographs which are not well made. Unfortunately, a very large proportion of the views commonly sold are far from perfect, and a considerable part of a dealer's entire stock which I recently examined was made up of views which were not stereo-

* He also argues that the perspectoscope obviates the necessity of extreme convergence as the eyes assume a natural position. This is true, but the objection holds against the Brewster stereoscope, not against all others. Further, this advantage is here gained at the expense of inverting the picture from right to left. He makes other inadmissible statements, which it is not necessary to consider here.

scopic at all, the two impressions of the photograph being *precisely alike*. It would, of course, be true that there would be no difference between a pair of such pictures viewed in the stereoscope and a single one of them viewed in the perspectoscope. The difference in this effect can readily be produced by any one who can procure two copies of the same pair of true stereoscopic pictures. Cut these in half and set up first either the two right or the two left halves, and then contrast this appearance with that obtained by viewing a right and left half. In this way the observer will soon train himself to recognize the difference between a genuine stereoscopic effect and one that only approximates it to a greater or a less extent. In the one case the object stands out with all the reality of life, while in the other case there is a relative flatness and only a pictorial type of perspective. It is something like the difference between viewing a model or a tableau and a picture; in the one case we have the difference in the two retinal images, together, of course, with all the accessory aids to the perception of depth, while in the latter case we have all the accessories but not the main factor. This experiment thus serves as an *experimentum crucis* and further indicates that it requires some little experience with stereoscopic effects to enable one to judge between the true appearance and those which more or less successfully imitate them.

It is quite an easy matter, however, to make a true stereoscope out of the perspectoscope; one need only make the reflecting mirrors adjustable and set them so that the one will reflect into the one eye one-half of an ordinary stereograph and the other mirror will reflect into the other eye the other half. Or the same result may be produced by a pair of fixed mirrors set at a suitable angle to so direct the reflected images for the stereograph of ordinary size. This form of construction for a simple and effective stereoscope has not, to my knowledge, been described.

The attempt to obtain a stereoscopic effect from a single picture has been frequently made, but in so far as it is successful it depends upon securing two dissimilar views of some picture which shall more or less closely imitate the differences between the two views of a stereograph. Le Conte Stevens* has clearly indicated that by the combination of a pair of perfectly similar conjugate pictures held inclined, like the two pages of a partly opened book, one may obtain a stereoscopic effect. In the same way photographs may be prepared from a single picture in which the picture is placed at an angle with the plane of the plate; and by suitable shifting of the angle one may secure two photographs of the original single photograph which will present differences similar to those in the two halves of a stereograph. This difference may be described by saying that in the right-hand view the left portion is somewhat crowded together and the right portion somewhat expanded, while the reverse is true of the left-hand picture. A pair of views, thus prepared, when placed in a stereoscope, give an approximate *stereoscopic effect*. In *Nature* (Feb. 3, 1898) Sir David Salomons describes an arrangement of lenses which will bring about such a distortion and will thus produce from a single picture the effects of depth. The device consists of a pair of wedge-shaped plano-cylindrical lenses, which, with their thicker edges set together, are fixed in position near the two prismatic lenses of an ordinary stereoscope and between them and the picture. A per-

* In the *Philosophical Magazine*, May, 1882. In the same place is described a reversible stereoscope which is much better suited to experimental purposes than the ordinary stereoscope, and merits a more general introduction in psychological laboratories than it has as yet secured.

sonal note adds the information that a thick cylindrical lens was used about $1\frac{3}{4}$ by $1\frac{1}{4}$ inches, with the concave surface a section of a circle, 6 inches in radius; that these lenses were fixed about one inch away from the stereoscopic lenses and about 3 inches from the picture.

I have prepared a pair of pseudo-stereographs from the one-half of a true stereograph, and could thus directly compare the life-likeness in the two cases. The advantage is entirely on the side of the true stereograph, not only on account of greater technical precision in the photographic plates, but because the degree and distribution of the dissimilarities of an actual view photographed by a stereoscopic camera more clearly imitate the retinal dissimilarities than do the two views of a photograph held at opposite angles with the camera. When I compare the result in the pseudo-stereographs with that of an arrangement like that described by Sir David Salomons (which, however, I have reproduced in general, not in precise detail) I regard the former as giving the better result. All these processes, however, are limited in scope and demonstrate that it is possible to produce a stereoscopic effect in a single picture only in so far as such a picture may be made to yield a pair of appropriately dissimilar views.

In this connection may be mentioned a device published in the set of Pseudoptics of Professor Münsterberg. It consists of a card suitably shaped to be held against the forehead and the ridge of the nose, so that the diagrams printed on the two sides of the card may be seen at close range, the one by the left eye, the other by the right, and then combined by projection outward upon a common imaginary plane. To allow for the fore-shortening of lines at this close range as compared with their projection, the vertical lines of the diagram are exaggerated in thickness as compared with the horizontal lines, and the nearer lines are proportionately heavier than the farther. This device presents a stereoscope in its utmost simplicity; but still it includes the combination of a pair of appropriately dissimilar views, and provides that each eye shall see only its own view. In the same connection may be mentioned another very simple device which is very useful for demonstration, but has not been generally described.* It may also be found in the set of Pseudoptics and consists of a pair of tubes about $1\frac{1}{4}$ inches in diameter and $8\frac{1}{2}$ inches long, over the ends of which are placed caps which contain on transparent paper the pair of stereoscopic diagrams. The tubes are simply held one before each eye and are rotated until the two diagrams are superimposed, when a stereoscopic combination takes place by simple convergence. This device is again limited in scope, for the diagrams must be small and not too elaborate.

Some years ago, in verifying the possibility, or rather the impossibility, of producing a true stereoscopic effect with a single picture, I attempted to utilize the principle of the telestereoscope. This principle consists in the reflection of images first from a pair of mirrors which meet at the point between the eyes and there form an angle of about 80°, and then again from a pair of mirrors farther away to the right and left and parallel to the first set. The ordinary stereograph is then viewed by reflection from the mirrors. In this stereoscope the path of the rays is long and the picture appears diminished in size. I have recently constructed such an apparatus with the two outward mirrors set on a pivot, with which I can view either single pictures or a pair of stereoscopic ones. This apparatus is, therefore, both a stereoscope and a perspectoscope, if by the latter

*It is described in the 'American Text-book of Physiology' (1897), p. 802.

term we mean an apparatus which in one way or another imitates a true perspective. As it lacks lenses (although these could be supplied), it does not yield such striking results as other stereoscopes, but is useful in illustrating clearly the difference between a combination of a pair of different views, for the change can be made from one to the other very quickly and without involving any other modification. I am not aware that the utilization of a telescope for this purpose has been previously described.*

In Hermann's 'Handbuch der Physiologie' (3, p. 587) may be found a description of a device, originating with Hirschberger, by which the picture is viewed near by with the eyes in nearly a parallel position, and thus an approximate stereo effect is produced with a single picture. This was accomplished by means of a pair of prisms; but as the arrangement is practically an inverted telestereoscope (with the outermost pair of mirrors adjustable and spread to the distance of the space between the eyes), I have used such an inverted telestereoscope for this purpose and with very good success. The effect of depth is much better than in the perspectoscope, especially when a pair of lenses is used with this device, but it is not as effective as in a double-picture stereoscope. Geometric diagrams seem distinctly projected in space, and photographic representations are almost as clear as in an ordinary stereoscope. In other words, there are all degrees of the stereoscopic illusion from flatness to perfect solidity, and this device represents about the maximum degree obtainable with a single picture.

* I have amongst my stereoscopes one in which the lenses are prismatic in one-half only, the other half being portions of true double convex spheres. By the rotation of each lens to a definite position we can use the apparatus simply as a pair of lenses and thus view a single picture at the proper focus. The instrument is called a stereo-graphoscope. In the latter form it is intended to accomplish just what the perspectoscope accomplishes, but it is not so convenient. The apparatus is very convenient as a stereoscope, because it admits of some adjustment of the positions of the two halves of the stereograph.

Another rather recent contribution is the combination of the stereoscope with the kinetoscope, thus producing the illusion of figures moving in three dimensions of space. Professor Münsterberg described such a device* in which the effect was obtained by viewing through a pair of series of slits of a large disc a single series of stroboscopic figures; the pair of series of slits is so arranged that one eye looks through the one, and the other eye through the other, and as the slitted disc and also the one with the figures rotate rapidly the two eyes obtain slightly different views of the stroboscopic figures; but the images follow one another so rapidly as to fuse and produce the illusion of motion and of depth. In a recent letter Professor Münsterberg informs me that the same effect may be produced by the use of a disc with one slit for both eyes and a mirror held a few inches behind the disc; for every slit there correspond two pictures drawn on the back of the disc, which when seen in the mirror furnish the appropriate pair of stereoscopic views. He also suggests that the same may be done by spinning such a disc upon a mirror with appropriate illumination. Dr. Sanford has also constructed a device for obtaining a stereo-stroboscopic effect.

The problem of projection by the lantern of stereoscopic pictures is receiving renewed consideration. The two methods most in vogue are those of the double lantern with the one view seen through green and the other through red light, and the other by application of polarized light. It is prob-

* See *Psychological Review*, 1894, I., p. 56. Also Scripture, 'The New Psychology,' pp. 431–435, where this and similar devices by Sanford (*American Journal of Psychology*, 1894, p. 576) and Dvorak are also described.

able, however, that these processes will be further simplified before they will meet with general introduction. I am informed that several devices are being considered which will enable the effect to be produced by means of a single lantern. Various principles involved in the forms of stereoscope above discussed make it evident that such a device is by no means impracticable.

This eclectic summary of the progress of invention in the field of stereoscopic vision would seem to indicate that the interest in this topic is undiminished and that the field is still open for improvements and modifications which shall be useful in exhibiting the principles which underlie the workings of this truly psychological instrument.

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## *CLASSIFICATION OF IGNEOUS ROCKS.**

PROFESSOR MERRILL remarked at the last meeting of the Geological Society that rock species do not exist in the definite sense in which this term is used in the organic world. Probably no petrographer will deny this conclusion.

Admitting, then, that rocks are mineral mixtures which may vary indefinitely, it is clear that the naming of these mixtures may be carried to excess. Let us, for example, take the feldspathic lavas. These may be divided into three great groups, the alkali-feldspar lavas or trachytes, the oligoclase-andesine lavas or andesites, and the labradorite-anorthite lavas or basalts. These three groups may be written graphically as follows :

The demands of modern petrography, perhaps, require the recognition of intermediate groups which may be designated by compound names. Thus a rock intermediate between syenite and diorite may be called a syenite-diorite. Such would be the rocks called mozonite by Brögger. Between the three great groups of feldspathic lavas above outlined there may be instituted three intermediate groups, as represented in the above diagram. One group intermediate between trachytes and andesites may be called the trachyte-andesite group ; that intermediate between the andesites and basalts the andesite-basalt group, and that intermediate between trachytes and basalts the trachyte-basalt group, or, as Washington has suggested, trachydolerite, adopting a term in use in Italy. The recognition of such intermediate groups seems to me quite desirable, but if the subdivisions are carried still further the results are, perhaps, of questionable value. To see how complicated the classification may easily become, let us take the single intermediate group of trachyte-basalts. There are in Italy, in the Yellowstone Park, near Buda-Pesth and in California rocks which occupy this intermediate position. These lavas have been studied by skilled petrographers, and their excellent descriptions, with the accompanying chemical analyses, leave no doubt as to their exact nature.

The following names have been proposed for different varieties :

Trachyte-basalt group :

| | |
|---|---|
| Yellowstone Park (Iddings) | Absarokite<br>Shoshonite<br>Banakite |
| Italy (Washington) | Trachydolerite<br>Toscanite<br>Vulsinite<br>Ciminite |
| Buda-Pesth (Koch) | Labradorite-trachyte |
| California (Ransome) | Trachandesite (Latite). |

Dr. Washington, in one of his admirable petrographic papers,* notes the close resemblance of his Italian lavas with those of the Yellowstone Park, but nevertheless

* Read before the Geological Society of Washington on February 9, 1898.

* *Journal of Geology*, Vol. V., page 363, 1897. See also table on page 366.